Closeout Presentation

Director's CD-1 Review of the CMS Detector Upgrade Project

July 16-18, 2013

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Executive Summary

This Fermilab Director's Review is to assess whether the US LHC CMS Detector Upgrade Project has met the DOE Critical Decision 1 (CD-1), "Approve Alternative Selection & Cost Range," requirements.

The LHC will resume operations in 2015 and is expected to exceed the design luminosity by as much as a factor of 1.5 after 1 - 2 years of running. The LHC then plans a long shutdown in 2018, after which will follow at least 3 to 4 years of operation at much higher luminosity, perhaps by a factor of 2 or 3, than it was originally designed to achieve and at which CMS was designed to operate. By 2019 peak luminosities are expected to reach 2-3 x 10^{34} cm^{-2} s^{-1}, corresponding to 50 to 80 interactions per crossing and 25 ns bunch spacing. The CMS detector requires upgrades, including upgrades to the systems originally provided by the US (the forward Pixelated Inner Tracking (Pixel) Detector, the Hadron Calorimeter (HCAL) Detector and the Trigger) to operate in these conditions.

The LHC CMS Detector Upgrade Project, funded by the DOE and NSF, will upgrade CMS detector components which were provided by the original US CMS detector construction project. The current plan is for a TPC estimated at $44.4M including a 35.6% contingency. The DOE would provide $32.68M and the NSF would provide $11.68M. Current planning calls for early project completion in April 2018 and a CD-4 date in the 1st quarter of FY19. The project was granted DOE CD-0 in September 2012 and will be reviewed for CD-1 in FY13.

The US CMS Upgrade Project team is a strong, capable team, with experience in the original US CMS detector construction project. At present the US CMS Operations Manager is also serving as the Interim Project Manager. Fermilab has identified a new, full-time Project Manager, who is a member of the USCMS collaboration and is on board now as a Fermilab employee. He will begin to serve as the PM after a period of overlap, transition with the current manager. The project team is a qualified, highly capable one having a good understanding of the existing CMS detector and the improvements necessary to operate efficiently while maintaining physics capability in conditions that will exist after the long shutdown in 2018. They are capable of completing the upgrade project successfully.

Science goals and physics requirements have been documented and translated into detector requirements and specifications; designs will likely meet these requirements and specifications. Designs can be constructed, inspected, tested, installed, operated and maintained; and prototypes exist for many of the designs. Documentation in support of the conceptual design is extensive and provides a good foundation for establishing a schedule and the cost range required for proceeding to DOE CD-1.

The project has developed a Resource Loaded Schedule and Cost Plan. A contingency analysis has been completed which considers maturity of design, risk assessment, and management judgment. Together these provide the basis for establishing a cost range of $40M to $47M which we consider to encompass possible outcomes with high probability.

The USCMS Upgrade Project should proceed to its DOE CD1 review after addressing the recommendations from this report.

1.0 Introduction

A Director's CD-1 Review of the LHC CMS Detector Upgrade Project was held on July 16-18, 2013 at the Fermi National Accelerator Laboratory. The object of this review was to assess if the project meets the Critical Decision 1 (CD-1) "Approve Alternative Selection & Cost Range" CD-1 requirements as specified in DOE O 413.3B. Additionally, the committee assessed the Project's progress on addressing the recommendations from the Director's Impendent Conceptual Design Review conducted on May 14-16, 2013 and the Director's Cost and Schedule Assessment was performed on May 15-16, 2013. The charge included a list of topics and specific questions to be addressed as part of the review. The assessment of the Review Committee is documented in the body of this closeout presentation.

Each section in this closeout presentation is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the project team. The remainder of this presentation has the answers to the review charge questions.

The LHC CMS Detector Upgrade Project is to develop a response to the review recommendations and present it to the Laboratory Management and regularly report on the progress during the Project's Project Management Group Meetings (PMGs) and at the Performance Oversight Group (POG). The recommendations will be tracked in the iTrack system where progress to closure will be tracked.

2.0 Technical

2.1 Hadron Calorimeter – HCAL

Primary Writer: Dmitri Denisov

Findings

- Present CMS detector hadron calorimeter will not be able to provide adequate performance for the high luminosity LHC operation.
- US CMS hadron calorimeter upgrade (WBS 401.2) is required to maintain CMS physics performance in high luminosity running after Long Shutdown II.
- Hadron calorimeter project consists of three sub-projects: 401.2.2 – forward front-end electronics upgrade, 401.2.3 – barrel/endcap front-end upgrade and 401.2.4 – electronics of the backend upgrade.
- The project is concentrated on the upgrades of electronics to improve detectors performance in high luminosity environment including replacement of photodetectors in central and end calorimeters with SiPMs.
- Technical performance of the proposed upgrade is described in the Technical Design Report (available).
- The project has well defined organization structure with all managers identified.
- US CMS hadron calorimeter upgrade is part of the CMS experiment upgrade with many of US CMS project members playing critical roles in the overall experiment upgrade.
- KPP parameters are well identified. Threshold KPP provides delivery of all upgrade equipment to CERN and tests of full functionality. Objective KPP extends to complete the installation of electronics and integration with the rest of CMS experiment.
- Project schedule covers period from FY13 (start of the project) to FY18 (completion of the project).
- The Project has developed a work breakdown structure and a resource-loaded schedule. They have defined a corresponding set of milestones.
- Total project cost (with contingency, but without risk contingency and top-down cost risk reserve) is $16M. It is split between NSF (30%) and DOE (70%).
- There are 13 risks and 3 opportunities presented in the risk register.

- US groups involved in this upgrade were responsible for CMS calorimetry during detector construction and operation in Run I.

Comments

- Proposed technical solutions for the hadron calorimeter upgrade are well developed, based on extensive R&D and are likely to satisfy physics goals of the CMS experiment during high luminosity LHC operation.

- The estimated cost range is reasonable and based on quotes and past experience of the project members with similar projects. Contingency assigned to the project cost is reasonable and in agreement with overall guidelines for the upgrade project contingencies estimate.

- All work activities are appropriately identified, estimated and scheduled.

- The proposed schedule is achievable. The objective KPP is constrained by the LHC schedule including limited time windows to install upgrade elements during long shutdowns and/or technical stops.

- In some cases the schedule is defined by funding profile. Appropriate funding is critical to deliver elements US is responsible for to the CMS experiment on schedule. Options of "forward funding" should be developed in consultation with funding agencies.

- The hadron calorimeter upgrade project identified project risks and proposed ways of mitigating these risks. Both list of risks and ways to address them are reasonable.

- The project team has deep experience in the detectors/electronics they are responsible for. In many cases the project has world best experts involved. The team demonstrates deep understanding of all relevant project details and interest to accomplish project on time and on schedule. The project team is capable to successfully accomplish the project.

- Availability of manpower profile for the full project and individual sub-projects will help to visualize staffing needs.

- KPP parameters of the project are well defined, reasonable and achievable based on the design, cost range and schedule presented.

- The scope of work is clearly defined between what is funded by NSF and DOE. Due to potentially different funding profiles from two agencies flexibility in the use of the funds from two sources has to be investigated with the funding agencies.

- The communication between US CMS project, CMS collaboration and CMS detector upgrade organization is well defined. Many of the US CMS upgrade

managers are also serving in CMS detector upgrade organization which will assure close communication and timely resolution of issues.

- The project provided clear and acceptable comments for 5 questions raised during Director's Independent Conceptual Design Review conducted on May 14-16 2013.

- Project managers demonstrated familiarity with project management tools including P6.

- Hadron calorimeter system upgrade team should be congratulated with developing sound project which will assure CMS experiment successful physics program during high luminosity LHC operation. The elements delivered by the US CMS hadron calorimeter upgrade are unique and success of the CMS experiment depends deeply on the success of the project.

- With minor improvements and clarifications this part of the US CMS upgrade project is ready for DOE CD-1 review in August 2013.

Recommendations

1. Develop preliminary options for "forward funding" in order to keep project on schedule if funding profile will be stretched.

2. Create a list of main deliverables by non-US CMS groups to the project which could substantially affect project cost and/or schedule.

3. Provide plots of manpower profile for different personnel categories: students, postdocs, engineers, staff scientists.

2.2 Silicon Pixel Detector – FPIX

Primary Writer: Dave Christian

Findings

- The upgraded FPIX detector will tolerate much higher data rate without loss of data than the current detector.
- The upgraded detector will include three disk layers in each direction.
- The upgraded detector will have lower mass in the tracking volume than the current detector.
- The new detector will use CO_2 cooling and operate at lower temperature than the existing detector.
- The upgraded detector will require more power than the current detector and higher output bandwidth, but will not require any new cabling external to the support cylinders.
- The upgraded FPIX detector will be constructed using a single type of module. The sensor modules will be produced by the same vendor that produced the existing FPIX sensors using the same technology as was used for the original sensors (on 6" wafers rather than 4" wafers).
- Bump bonding and flip chip assembly of sensor-readout chip hybrids will be done by one or two commercial vendors, well known to the CMS group.
- Fabrication of detector modules from hybrids and high density interconnect circuits will be done at two university sites, using identical robotic assembly procedures.
- The pixel readout chip (ROC) will be supplied by PSI. The most significant ancillary ASIC will be a new "Token Bit Manager" (TBM). Both of these ASICs are modifications of ASICs used in the existing detector and both will be fabricated in the same 0.25 micron CMOS process as was used for the current generation ASICs. Near-final versions of both of these ASICs are in hand. The final readout chip submission is planned for December 2013.
- One new type of "High Density Interconnect" (HDI) is required; a prototype has been fabricated.
- New "port-cards" will be located in the pixel service cylinder and will translate high-speed output data from electrical to optical signals. DC-DC converters will be located near the port-cards. The use of DC-DC converters (and 10V power

distribution to the support cylinders) is crucial, since this is what will allow the existing power cabling to provide sufficient power to the new detector.

- A new aluminum flexible cable will carry power, HV, and signals between pixel modules and port-cards. These cables will be provided by the CERN printed circuit board shop.

- Plans for the replacement "Front End Digitizers" (FEDs) have not been finalized; two solutions are under study.

- The new half disk mechanical and cooling design is significantly different from that of the installed detector. The new half disk is divided into mechanically separate inner and outer half rings.

- Since the Director's Conceptual Design Review in May, the CMS group has decided to include early construction of a full prototype half ring in the project plan.

- The service cylinders for the new detector will be very similar to the existing service cylinders. The fixtures used during installation and installation procedures will require only minor modifications.

- A detailed cost estimate and resource loaded schedule was presented.

Comments

- Increased rate capability is essential to the continued efficient operation of sections of the pixel detector closest to the circulating beams.

- Operation at lower temperature will provide increased confidence that the upgraded FPIX detector will be sufficiently radiation tolerant.

- The increase in the number of pixel layers is very well motivated by Monte Carlo studies of tracking in the presence of the projected number of pileup events.

- A design using one module type simplifies module fabrication and is recognized as a "best practice." It also significantly reduces the risk associated with sensor and bump bonding yield compared to a design requiring many sensor types.

- The planning of module assembly procedures is well advanced. The plan to build 50 sensor modules using prototype sensors and prototype ROCs will allow these procedures to be fine-tuned well before production begins.

- The current prototype ROC has been shown to perform well enough for use in the pilot system, and would probably have sufficient rate capability for use in the upgraded FPIX detector.

- Sensor and ROC development is sufficiently advanced that the associated cost and schedule risk is small.

- The pilot system represents a small fraction of the cost of the FPIX project, but it is a very important part of the project and will provide realistic early tests of hardware and software performance.

- The construction of a prototype half ring will not only validate procedures that are being developed to connect blades to half rings, but will also provide a test bed for the validation of HDI and aluminum flexible cable performance, and for system tests.

- The vast majority of the items in the cost estimate and resource loaded schedule are conservatively estimated and are based on experience gained in the construction and operation of the existing CMS pixel detector.

- The cost estimate and resource loaded schedule are based on a detailed and thoughtful analysis of all of the components and assembly steps required. The result is a high quality estimate of the cost, level of effort, and time required to successfully complete the FPIX upgrade project.

Recommendations

None

2.3 Level 1 Trigger

Primary Writer: Eric James

Findings

- The trigger project upgrade is driven by the expected increases in instantaneous luminosity expected before and after LS2. Luminosities are expected to rise to ~ $2x10^{34}$ by the start of LS2 and go higher afterwards. The corresponding rise in the number of interactions per crossing can be somewhat mitigated by changing the beam crossing interval from 50 to 25 ns, but this is technically challenging for the accelerator and not guaranteed to happen.

- A base cost estimate of 5.5 million dollars with an added contingency of 33% was presented for the trigger project.

- A resource loaded, technically driven schedule was shown with a trigger project completion date of late FY16.

- Threshold and stretch key performance parameters were presented for the trigger project, focusing on demonstration of system functionality through comparisons of observed and emulated trigger data and the performance of the new algorithms on reducing trigger rates.

- The trigger project team is made up of the same key people who designed and built the equivalent systems currently installed in the CMS detector. The potential loss of one or more of these experienced team members was identified as the most significant potential risk to the project.

- The trigger project team has identified the development of firmware and software associated with the trigger hardware as the driver of the critical path for the schedule and as the biggest source of uncertainty within the cost estimate.

- The trigger project presented a staged installation plan, which would potentially allow for some enhanced trigger functionality as early as 2015. The plan focuses on the early installation and commissioning of a few key hardware components, representing a relatively small subset of the full set of trigger upgrade hardware to be produced.

Comments

- The trigger project has adequately addressed the recommendations from the conceptual design review by moving the production of boards needed to be installed prior to the end of LS1 to the CMS operations budget and by modifying the conceptual design report to much more clearly describe constraints affecting the design of the upgraded trigger system.

- Cost estimates associated with the production of boards are very believable since working prototypes exist in all cases. The trigger project managers correctly assign a high level of contingency (~40%) to labor estimates associated with the development of required firmware and software.

- Because of the experience of the team assembled to complete the trigger project, the current labor estimates are also very believable. The trigger project managers correctly identify losing one of these key contributors as their most significant project risk.

- The trigger project has put together a credible plan for installing and commissioning the upgraded systems in parallel with continued operation of the current systems. For this reason, the Key Performance Parameters defined by the trigger project are completely decoupled from the operation of the CMS detector and should be readily achievable within the required timescale.

- Based on the current state of board prototyping, the presented technically driven schedule for the trigger project, for which firmware and software development efforts define the critical path, is credible. Schedule issues should be re-examined once the expected project budget profiles have been folded in.

- Concerns regarding the impact of rapidly increasing luminosity at the beginning of the upcoming LHC run on the CMS physics program are valid. If the accelerator is found to not be able to operate with a 25 ns bunch crossing, the associated trigger issues will become a major problem even more quickly. With this in mind, the review committee strongly supports proceeding with the proposed plan for installing and commissioning an initial small subset of upgraded trigger components as soon as possible.

Recommendations

4. Prior to the upcoming CD-1 review, initiate discussions on obtaining CD-3a approval for production of components needed for the initial steps in the proposed staged installation plan. These components will be essential for maintaining current trigger performance, especially if the accelerator is unable to operate with 25 ns bunch spacing.

3.0 Cost and Schedule

Primary Writer: Bob O'Sullivan

Contributors: David Leeb

3.1 Cost

Findings

- The project cost estimate is well developed and includes all anticipated project scope. The estimate provides all required overheads, laboratory indirects, anticipated cost escalation and contingencies.

- The cost estimate is organized following the detailed WBS structure, and provides for a detailed, activity based estimate.

- The schedule has been integrated with the Cobra cost processor, to develop the project estimate. The Cobra application applies labor rates and escalation and overheads for all scheduled costs, and calculates estimate uncertainty values. Costs associated with identified risk register items are not included in the Cobra materials.

- The project cost estimate as presented at the review is $44M, including 36% contingency. The top end of the cost range, $47M, includes an additional 7% contingency, for a total of 43% contingency.

- In the 401.01 schedule, the "Teaching buyout for NSF Principal Investigator" activities are included in the Cost Profile but are not included in the Obligation Profile

- The FPIX and HCAL schedules include work activities that remain to be resource loaded.

- The project awaits the NSF Funding Profile.

Comments

- The cost estimate is mature beyond what is expected for a CD-1 review.

- The project cost estimate, as presented, is well developed, and provides adequate contingency based on the maturity of the design. The project cost estimate provides a reasonable forecast of the total project cost.

- Best practices suggest implementing consistent rules for assigning costed vs. uncosted post-doc, grad student and undergrad student labor across the project.

- Slides may be added to the cost presentations showing the Cost Estimate Type used across the projects elements (L2, L3). At Level 2, this information can be

cross checked against the assigned estimate uncertainty, risk-based and top-down contingencies.

- When citing past project experience within the BOE forms, the project names can be referenced to provide additional confidence.

- WBS 401.02.03.09 - Low Voltage System Modifications is defined in the WBS dictionary as being off project, however it has estimated costs included within the cost estimated.

- Include the "Teaching buyout for NSF Principal Investigator" activities in the Obligation Profile

- When building the cost range, consider following the approach outlined in DOE guideline 413.3-21 – Cost Estimating, appendix H. Characterize Design Maturity at Level 2 and Level 3 for validation of the cost range.

Recommendations

Required for CD-1 Review

5. The CMS team should perform a BOE audit and clean up the backup documentation. Confirm the quantities included in BOEs document can be traced to supporting documentation. Peer review would be considered a best practice.

6. Ensure all activities within the schedule are resource loaded as applicable. This includes the activities within the FPIX and HCAL sub project schedules that remain to be resource loaded.

7. Develop a list of candidates for scope enhancements and reductions; include the additional work associated with attainment of the Objective KPPs.

8. Calculate the % contingency based on remaining contingency on "cost-to-go".

To be completed after CD-1 Review

9. Evaluate "Project Support" staffing during the EVM portion of the project to ensure the correct resource ID has been assigned.

10. Use costed resources for "Project Engineering" activities in project management sections of the schedule.

11. Ensure consistent rules for assigning costed vs. uncosted post-doc, grad student and undergrad student labor are applied across the project.

12. Check the schedule to ensure there is no off-project work resource loaded within the schedule (e.g. WBS 401.02.03.09 - Low Voltage System Modifications).

3.2 Schedule

Findings

- The Project Team members are knowledgeable of the schedule and able to demonstrate how the work will be executed.

- The Project has a P6 schedule with 2489 activities with 3664 relationships and has a completion date of April 2018 to meet the threshold KPPs and December 2018 to meet the objective KPPs.

- The project has well developed WBS Structure and WBS dictionary, which was used as the structure for the P6 schedule.

- The team has provided an advanced work plan, which demonstrates how the technical scope of work can be achieved.

- The project schedule is resource-loaded with labor hours and materials and services costs in US Dollars. It includes coding required to integrate these quantities into the Cobra cost tool for the development of project costs.

- The project schedule has been extensively modified and developed since the May 2013 Director's cost & schedule assessment. Many recommendations made at the May assessment have been completed.

- The P6 schedule is technically driven, except for a few areas in which funding constraints have been added to the schedule. In some places, these constraints impact the critical path.

Comments

- The schedule represents the technical work required to complete the project beyond what is expected for a CD-1 review.

- The logic network developed through each L2 schedule is robust.

- The schedule needs to be aligned with the Assumption document in many areas. For example, the assumptions document references procurement durations and calendar limits are not included in the schedule and some university scientists are costed to the project.

- Actual past period performance has not consistently been reflected in the schedule.

- Schedule Gantt Charts and BOEs should include the funding source associated with each task for use by reviewers.

- The mezzanine card replacement activities on the Trigger L2 project, which have been transferred to CMS operations, should be removed from the resource loaded schedule.

- Given time pressures, consider adding a seasoned Project Controls staff person to get the schedule CD-1 ready.

Recommendations

Required for CD-1 Review

13. Once the resource loaded schedule is developed, provide at least 1 year of schedule float relative to the CD-4 early completion date.

14. The project should provide a date as of which the resource loaded schedule reflects actual work performed.

15. The assumptions document should be updated to reflect how the RLS is built for the CD-1 review.

16. Incorporate detailed activities and milestones associated with CD reviews and CD signoffs (attainment). Review funding type of all activities relative to CD approvals.

17. Ensure the obligation profile, plus desired contingency, is equal to or below the funding profile in each year.

18. Discuss inclusion of a CD-3a with the DOE and add activities and logic to the schedule required to execute advanced implementation of selected scope, including the Trigger production hardware.

19. The schedule critical path is funding driven. The team should work to optimize the obligation profile, while minimizing impact to the critical path.

20. A quality check should be made on P6 activity codes including funding type, EDIA, and cost class as these codes are crucial for CD-1 presentation graphics.

To be completed after CD-1 Review

21. Update the Project Management resource IDs assigned to all project management and risk management resource assignments.

22. Procurement planning packages should be added for all material procurements, MOUs and statements of work.

23. Schedule Milestones should be coded and named for proper hierarchy level.

24. Update all subprojects to have a common data date.

25. Remove constraints from the schedule which do not represent external impositions on the project; provide correct predecessor and successor relationships for all project activities;

4.0 ESH&Q

Primary Writer: John Anderson Jr.

Contributors: Kathy Zappia

Findings

- Drafts of the Quality Assurance Program (QAP), Integrated Safety Management (ISM) Plan, and Preliminary Hazard Analysis Report (PHAR) for CD-1 have been prepared.

- In accordance with 10 CFR 1021, National Environmental Policy Act (NEPA), the LHC CMS Detector Upgrade Project was granted a Categorical Exclusion by DOE-FSO on 1 July 2013.

Comments

- ESH&Q is being adequately addressed throughout the project.

- Major ESH issue is the coordination necessary to deal with differing safety requirements depending on where the work is taking place, e.g. university, Fermilab, CERN.

- Designs need to meet the various safety requirements of all the facilities that it will move through.

- Each of the participating institutions has well established ESH&Q programs.

- Project has significant experience working between multiple institutions and countries.

- Quality Assurance aspects for testing and calibration of components and modules are being implemented into the design, prototyping, and construction activities.

- Each L2 and L3 presenter should incorporate ES&H and QA slides in their plenary presentations. The slides should identify the significant ESH&Q aspects of their portion of the project. See HCAL presentation for an example.

- The PHAD Attachment B should be updated to reflect the CO_2 toxicity hazard.

- With minor improvements and clarifications, the ESH&Q aspects of the US CMS Upgrade Project are ready for DOE CD-1 review in August 2013

Recommendations

26. Identify a Project Quality Assurance Manager.

27. Finalize and approve the ISM, QAP, and PHAR documents before the CD1 review.

Management

Primary Writer: Ed Temple

Contributors: Marc Kaducak; Mike Dinnon

Management – High Level Point of View

Findings

- The staff for the US CMS Upgrade project is largely already in place or at least personnel who will fill the required positions have already been identified by name.

- Most if not all the team members participated on the original successful CMS Construction Project and have continued on the CMS program during LHC / CMS operations to date.

- The Project Office team is in place. Two key positions to be added in FY14-15 are a Project Mechanical Engineer and a Project Electrical Engineer.

- A newly identified US CMS Upgrade Project Manager was introduced at this review. This individual has been on the CMS team for many years and prior to that worked on the CDF experiment at Fermilab.

- Additional Project Controls support has been provided since the Cost Schedule Review that was held in May.

Comments

- Given their prior participation on the CMS Project, CMS Operations, and Upgrade preparatory activities, the US CMS Upgrade Project staff has an extensive background and experience.

- This Project Team can most definitely successfully complete the project.

- The newly identified Project Manager has experience on CMS and at Fermilab which will be useful in his new role. However, he's likely to benefit from a significant overlap with the current Deputy Project Manager who can provide guidance on project management specifics as he settles in to this new role. Access to the current Project Manager for "corporate memory" reference may also be critical for an extended period.

- The US CMS Upgrade project extensively detailed WBS and RLS (including BoE documentation) provide a sound formal framework for creating the project cost estimate and detailed technically driven schedule.

- The resulting base estimate and project activity durations, developed by this very experienced team, are judged highly credible.

- Even with the additional Project Controls support, the revised P6 schedule was not completed in time to perform the iterations required to "match funding profile guidance."

- There are other required improvements to the schedule as well that are described in the Cost and Schedule section of this report.

- At the request of this Review Committee, the project team provided a list of procurements over $100K each along with the award dates.

- One of the documents required by the laboratory in support of CD-1 is a Procurement Management Plan. The list of procurements noted above could serve as an important appendix to this Procurement Management Plan.

- The list of procurements and the Procurement Management Plan can serve as a key vehicle for conveying to the funding agencies the planned project approach in this arena at the CD-1 Review. The important concepts include 1) OPC funded R&D, prototype, and pre-production activities and 2) a CD-3a request for early hardware procurement needed for installation in the LHC Extended Technical Stop and to support early programmatic capabilities as the machine turns on with increased luminosity.

Recommendations

28. As host for the US CMS efforts, Fermilab should continue to provide strong institutional support for the US CMS Upgrade where possible, perhaps including specific actions to support the new Project Manager as he comes up to speed.

Project Management – Detailed Point of View

Findings

- The project management staff includes a project manager at 100% level of effort, two deputy project managers at 50% each, a project controls specialist at 100%, a financial analyst at 25%, risk manager at 25%, and mechanical and electronics project engineering at a combined total of 25%. These levels of effort taper off after FY17.

- The current project manager is considered interim and is also the current CMS Operations Manager. A new project manager has very recently been identified and will officially take over following CD-1. There will be overlap between the existing and new project manager. The deputy project managers are also listed as interim.

- Drafts of all required CD-1 documents exist.

- The Key Performance Parameters (KPPs) in the draft Preliminary Project Execution Plan include threshold (minimum requirement of success) and objective (stretch goal) levels. The threshold objectives generally correspond to delivery of systems and the objectives generally correspond to installation of these systems.

- The total base (w/o contingency) cost estimate for project management is $5.4M, including $4.9M from DOE and $0.5M from NSF funding. The total base (both funding sources w/o contingency) cost of the project is $32.7M.

Comments

- External management interfaces exist with the NSF, CERN, the CMS collaboration, and CMS operations. The US CMS Upgrade project team is already fully integrated and effectively functioning within this system.

- The project schedule, especially for FPIX, is driven by an assumed Extended Technical Stop (ETS) of the LHC in FY16, which has not yet become part of the official CERN plan. However, the project has carefully constructed the threshold Key Performance Parameters (KPPs) to provide independence between project deliverables and the LHC shutdown schedule. Therefore the "success of the project," from a formal point of view, is less likely to hinge on the LHC schedule.

- The presentations were, in general, too focused on technical details. Presentations for the DOE CD-1 review should be focused on concise descriptions of the scope, cost, schedule, organization, and responsibilities. More time for discussion should be allotted in the management breakout session.

- The functions and level of effort of existing and planned project management staff seem adequate. Additional Project Controls effort could be required, especially in preparation for CD-2 depending on its schedule.

- The project has generated drafts of all the required documents for CD-1, but key information regarding cost and schedule is missing or out of date. There are also some corrections such as the PHAR incorrectly prescribing a Safety Assessment Document is planned, and the PPEP describing the project as a line item. Each draft CD-1 document will require a careful proofreading.

- An incomplete procurement plan was presented together with a separate list of procurements. These two pieces can be combined into a single procurement plan. NSF funding will be used for some early production procurements. CD-3a should also be considered so construction related procurements can proceed. Phased procurements, e.g. with options, could be considered to alleviate other obligation versus funding guidance discrepancies.

- Costs were often presented as "TPC0", which included estimate uncertainty contingency but no other risk based or "top-down" contingency. This concept of TPC0 unnecessarily caused confusion and should not be used. All high level cost

presentations should represent the entire DOE TPC including all contingency and NSF funded scope should be clearly identified.

Recommendations

29. Identify required early activities and procurements that require CD-3 approval and request a CD-3a for them.

30. Identify signatories for and complete all required documentation (PPEP, Acquisition Strategy, Risk Management Plan, ESH, and QA) for CD-1.

31. Add the list of procurements to the procurement plan document.

32. Design the DOE CD-1 review presentations to focus on scope, cost, schedule, management, and responsibilities.

33. Include all types of contingency when presenting costs at the DOE CD-1 review

Risk Management

Findings

- The Integrated Project Team (IPT) is very capable and demonstrates a good working relationship.

- The Project presented documentation required for CD-1.

- The Project presented contingency rules that justify the estimate uncertainty.

- The Project Team presented a risk register with 56 threats and 25 opportunities and a Preliminary Risk Plan.

- Of the 81 total risk entries, 5 are medium risks, one is a high risk and 75 are low entries.

- The Project requirements are contained in each sub project's TDR and an Independent Conceptual Design Review has been completed in May 2013 verifying the design.

Comments

- The Project should reassess "top down" contingency items that are "known" and add to the Project Risk Register. When complete, recalculate Top Down contingency.

- The project should document standing army costs that can be used in the risk analysis to estimate possible cost impacts associated with possible schedule delay risks

- The Project should look to include PM risk items such as; delays related to Continuing Resolution, difficulties with funding profile, etc.
- Schedule elements of the risk register should be updated when the Critical Path from the updated schedule is known.
- The Project should keep in mind risk events and management reserve plus contingency associated to each year when matching to a funding profile.
- The Project Risk Manager should be present for the DOE CD-1 Review.
- Formulate and document a scope contingency plan.
- Have appropriate sign offs on documents prior to the DOE CD-1 Review.
- A Project wide Risk workshop should be conducted when possible to understand any possible interdependencies in risk amongst sub projects.
- Quality Oversight should be accounted for in the Project Office.
- The appearance of mostly low ranked risks in the risk register raises an issue as to if the analysis impact matrix may be skewed to the lower end.

Recommendations

34. Analyze the risk matrix and make changes to show a more realistic interpretation of impact level.

35. Complete risk analysis with the use of the updated schedule and distinguish between DOE and NSF risk related events.

36. Update documentation to include correct numbers that will come from the updated schedule.

5.0 Charge Questions

6.1 Has the Project developed a quality resource loaded schedule that includes the entire project's scope of work and is it achievable?

The project has completed much work on the resource loaded schedule since the May assessment, and has presented a technically-driven resource loaded schedule. Continued development of the schedule to include Critical Decision review activities, appropriate logical relationships to those CD approvals, and obligation leveling relative to the funding profile will generate the desired confidence in the critical path and project completion target.

6.2 Are the estimated cost and proposed schedule ranges realistic, consistent with the technical and budgetary objectives, and justified by the supporting documentation? Has all the work been appropriately identified, estimated and scheduled, including the work associated with performing the preliminary design, final design and value engineering activities?

The project cost estimate as presented at the review is $44M, which includes 36% contingency. The current top of the cost range is 47M, which provides a total contingency of 43%, which seemed reasonable based on the design maturity assessment of the technical review team. DOE guideline 413.3-21 – Cost Estimating, appendix H, should be used to validate the cost range developed for the DOE CD-1 review. Also, once the resource loaded schedule is developed, it is recommended that there be at least 1 year of schedule float relative to the CD-4 early completion date.

6.3 Has the Project implemented a Risk Management Process by identifying risks, performing a risk assessment and started developing mitigation plans at an appropriate level for the CD-1 stage?

Yes, The Project has identified risk events and completed a preliminary assessment establishing the risk process that includes beginning mitigation planning. After completing recommendations from this review, risk management will be ready for CD-1.

6.4 Is the Project Team adequately staffed and does it possess adequate experience to successfully carry out the Project?

Yes. The Project Team is well staffed and the staff personnel are quite experienced. This team can successfully carry out the Project

6.5 Is the current staffing level adequate to complete the work to achieve CD-2? If not, has the appropriate staffing level been identified in the schedule and has a staffing plan been developed to acquire the future staffing needs?

Yes. The current level of staffing can quite handily complete the work to achieve CD-2. Furthermore, there are already clearly identified personnel to carry the effort through the completion of the project!

6.6 Are ESH&Q aspects being properly addressed given the project's current stage of development?

Yes. Drafts of the ESH&Q Documentation requirements for CD-1 have been prepared.

6.7 Are the draft Key Performance Parameters (KPPs) achievable based on the design, cost range and schedule range presented?

KPPs for WBS 401.02, 401.03 and 401.04 are achievable based on the design, cost range and schedule range presented. The project should consider more uniform approach for KPPs between sub-projects including stating only additional goals for the objective KPP and assure that phrasing of KPPs is exactly the same in all documents/presentation.

6.8 Is the scope of work clearly defined between what is funded by DOE or NSF, and is this reflected in the cost, schedule and risk assessment presented to the committee?

The P6 schedule includes funding type codes related to DOE and NSF, which has been used to delineate the work.

6.9 Has the relationship been clearly defined between the LHC CMS Detector Upgrade Project and International CMS at CERN?

Yes, modulo the fact that management personnel (and in some cases procedures) on both the US CMS Upgrade project and International CMS are changing. The general approach is to incorporate the relationships, interactions, points of contact, and approvals that were in place on the original successful CMS project.

6.10 Has the project acceptably addressed the relative recommendations from the Director's Independent Conceptual Design conducted on May 14-16, 2013 and the Director's Cost and the Schedule Assessment performed on May 15-16, 2013?

The recommendations made at the May 14-16, 2013 Independent Conceptual Design have been addressed, however the Project Team continues to work towards completion of the recommendations provided from the May Cost and Schedule Assessment. Many of recommendations from the earlier assessment have been included in the Cost and Schedule section of this report, as applicable.

6.11 Is the documentation required by DOE O 413.3B and Fermilab's Project Management System in order and is the Project ready for a DOE CD-1 review scheduled for August 26-27, 2013?

Drafts of all required documents required for CD-1 have been prepared. The project provided a status of all CD-1 requirements at this review. Documents range from being ready for CD-1 to requiring updates.